Second Australian Stream Management Conference
8-11 February 1999, Adelaide, South Australia

Fishways - an element of stream rehabilitation: some issues, recent successes, and research needs

Lindsay J. White[1] *and Tim A. O'Brien*[2]

SUMMARY
Many instream structures (including dams, weirs and culverts) can act as barriers to the migration of native freshwater fish species. This impact is significant to many native fish species because the instream structures may, for example, reduce the opportunity to reproduce or to access preferred habitat. To mitigate this impact, fishways have sometimes been built adjacent to these instream structures.

THE MAIN POINTS OF THIS PAPER:
- provides some information on the propensity of Australian freshwater fish species to migrate;
- provides estimates of the number of artificial barriers to fish migration in some eastern states of Australia;
- provides two examples of recently constructed fishways that fish are using; and
- identifies some of the research that is needed on fish passage issues.

1. INTRODUCTION

The numbers of some native freshwater fish species are rapidly declining in many streams (Harris and Gehrke 1997). The decline in abundance of native freshwater fish is typically attributed to factors such as: general habitat degradation such as sedimentation, desnagging, channelisation; interrupted migratory pathways; modified patterns of streamflow; reduced water quality, and pollution; introduction of alien fish and diseases; recreational and commercial overfishing; changed energy fluxes (carbon movement etc); and altered biotic interactions (Harris and Gehrke 1997). The relative importance of each of these factors will vary from stream to stream.

The remainder of this paper focuses exclusively on one of the above factors: **interrupted migratory pathways.**

In the context of stream rehabilitation, the importance of the issue of instream structures blocking fish migration was highlighted succintly by Koehn (1995) with the statement *'habitat is of little value [for fish] if fish cannot get access to it'***.** Hence, fish passage should be a fundamental consideration in stream rehabilitation.

1.1 Migration of southeastern Australian fish species

Some statistics on the number of native migratory fish species in southeastern Australia are given below.

1. In south-eastern Australia, over 40% of freshwater fish species 'make large scale movements or migrations that are essential for the completion of their life histories'–(Mallen-Cooper and Harris 1990)
2. In the southern drainage division of Victoria, 60% of the native freshwater fish species are considered migratory (Raadik 1995). In the northern division, 17% of the species are considered migratory.
3. Some estuarine fish species also migrate into freshwater on occasion. For example, of the 66 estuarine species recorded for East Gippsland, in far east Victoria, 14 have been recorded in freshwater on a number of occasions (Raadik 1992).

Fish species migrate upstream (or downstream) for a variety of reasons including:
- the completion of life cycles (including spawning);
- to optimise available habitat (which is particularly important in streams with highly variable flows); and
- to compensate for the downstream drift of pelagic eggs or larvae (Reynolds 1983).

For some fish species, migration is obligatory for the completion of their life history, for others it is facultative (ie. it may not be essential for the completion of the life history but it may be important to maintain the distribution of the species).

1.2 Prevalence of instream structures

Artificial barriers to fish migration are widespread in Australia. For example
- there are 4 000 known barriers in NSW (Leader and Smit 1997);
- there are 2 500 potential barriers throughout Victoria, with about 150 dams, fords, culverts and erosion control structures being constructed on Victorian streams annually (Bennett 1997); and

[1] CRC Catchment Hydrology, Monash University Clayton VIC 3168

- there are 600 artificial barriers in the Queensland portion of the Darling River alone (Jackson 1997) and over 1 500 dams and weirs in the Murray-Darling Basin without fishways (Mallen-Cooper *et al*. 1996).

In eastern Australia from the Mary River in Queensland to the Gippsland Lakes system in Victoria, on average 32% of the total smoothed valley length is blocked to fish migration due to physical barriers (Harris 1984).

Given the prevalence of instream structures and the need for many native fish species to migrate, it is understandable why artificial barriers are often identified as a factor contributing to local extinction's and the general decline of the numbers of native fish.

1.3 Attempts to provide fish passage in Australia prior to mid 1980's

Between 1925 and the mid 1980's, more than forty fishways were built on the rivers of southeastern Australia (Mallen-Cooper 1994). These fishways were typically based on designs imported from the Northern Hemisphere for salmonid species. However, Australian native freshwater fish species are quite different to salmonid species in their ability to pass barriers as they generally: can not swim as fast; do not tolerate the same levels of turbulence; and are reluctant to leap. As a consequence, few native fish are able to pass most of the fishways constructed prior to the mid 1980's. For example, Hajkowicz and Kerby (1992) examined information on 13 existing fishways in Queensland and concluded that: 5 were ineffective; 3 were limited in their effectiveness; 3 were moderately effective; 2 were of unknown effectiveness; and none would allow the passage of barramundi.

1.4 Recent fishway successes

Although fishway research in Australia has lagged behind much of the rest of the world for many years (Mallen-Cooper 1992), some research has been undertaken since the mid 1980's and some fishways have been designed to perform effectively. Brief descriptions of two recent fishway successes are provided below.

A vertical slot fishway was completed at **Torrumbarry Weir** on the River Murray in 1991. This project was discussed in (Mallen-Cooper 1996). This was the first fishway in the Murray-Darling Basin designed on the basis of data on swimming ability of native fish obtained in a laboratory. A schematic of a vertical slot fishway is provided in Figure 1. Some of the key findings from monitoring of fish movement through Torrumbarry Weir were:

1. More than 20 000 native fish and 16 000 carp used the fishway in the first 2 1/2 years of operation. Four native species - golden perch (*Macquaria ambigua)*, silver perch (*Bidyanus bidyanus*), bony herring (*Nematalosa erebi*) and Australian smelt (*Retropinna semoni*) migrated upstream in large numbers through the fishway.
2. Virtually an identical size range of native fish, except for Australian smelt (*Retropinna semoni)*, was collected at the top and bottom of the fishway, indicating the successful passage of these native fishes .
3. Small rises in river level, of 0.2 to 0.8 m per week, appeared to stimulate native fish to move upstream through the Torrumbarry fishway. Rising water temperature appeared to stimulate carp to migrate.
4. Some fish took up to 3 hours to ascend through the 39 pools in the Torrumbarry fishway. Some species (eg. silver perch and bony herring) would only migrate during daylight hours – if they did not complete their ascent during daylight they would return down the fishway.

The second example discussed is a rock ramp fishway constructed **on the Barwon River near Geelong**, Victoria (1.5 km upstream of Lake Connewarre) in 1995. This example is described more fully in (O'Brien 1997). The width of the rock ramp was about 2.5 m, the vertical drop was 0.75 m high, and the slope was 1 vertical: 16 horizontal. This fishway cost about $10 000 to construct.

Subsequent monitoring showed that the small native fish passed the fishway. More than 10 000 fish were trapped after moving through the fishway during one night. These included three species of Galaxias, Short-finned eels (*Anguilla australis)*, Australian smelt (*Retropinna semoni*) and Tupong (*Pseudaphritis urvillii*) with the smallest migrating fish in this system (40 mm) being able to pass.

General lessons from these two fishway successes include:

- it is often relatively easy to do fish counts at the upstream end of fishways (but, as discussed briefly in the following section, this does not necessarily prove that the fishway is working effectively);
- it is possible to design fishways that work effectively if adequate information is known about swimming ability and behaviour of the fish species in the system;
- native fishes will use a vertical-slot fishway
- in some circumstances, it is possible to cost effectively retrofit rock ramp fishways to weirs with low head (up to about 1.5 m) across them; and
- rock ramp fishways can work effectively for some, and probably many, Australian fish species.

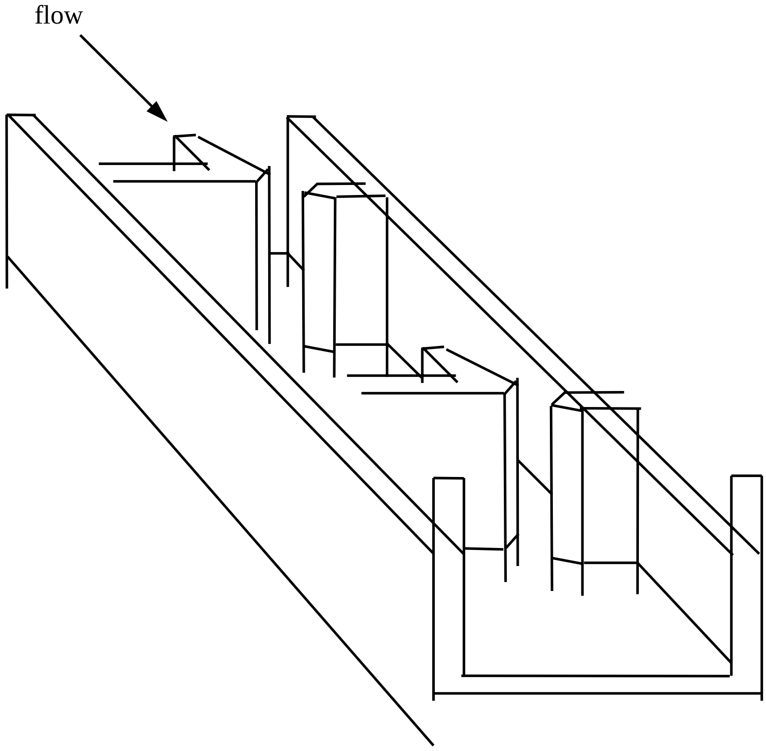

Figure 1 – Schematic of a vertical slot fishway (after Mallen-Cooper, 1998)

2. REQUIRED FURTHER RESEARCH

Although some of the recently constructed fishways appear to be working effectively, including those discussed in the previous section, there is still a lot to learn about fishways. In particular, some fish passage issues needing research include:

- **the triggers of commencement of fish migration**, and how it is related to one or a combination of change in flow, increased water temperature, photoperiod, greater availability of food, and the lunar cycle. This knowledge is important so that human changes to streams can be managed to not eliminate the stimuli of fish to breed.
- **relationship between fish migration and flow**. Of recent interest are the range of high flows over which fish are migrating. This determines the design parameters of the fishway, which has a direct influence on the capital cost of the fishway. Designing fishways that function for very low flows is also an important issue that is particular to the hydrology of Australian streams and the migration of Australian fishes. A knowledge of the link between fish migration and flow will also be important in determining environmental flows.
- **upstream extent of fish migration in the vicinity of an instream barrier**. This might be governed by water velocity, turbulence and depth. It is important in locating the entrance to a fishway.
- **swimming ability**, over different combinations of velocity, turbulence, and water temperature. It may be possible to develop generic relationships between fish swimming ability and geometry, or fish anatomy (eg. % of body mass that is white and red muscle). These relationships could be used when estimating the velocities that a fish of a certain size and shape is likely to be able to pass – which is an important design consideration.
- **behavioural characteristics.** Some fish species may swim better in schools than in isolation. Others may prefer to avoid dark tunnels, or shallow water. When designing fishways, it is important to keep these behavioural characteristics in mind.
- **downstream migration of fish (including larval fish)**. Often fishways are designed with a focus on upstream migration. Downstream migration is also important for many species. A better understanding may lead to fishways which are passable in both upstream and downstream directions.

Other broader fish passage issues requiring further research include:

- **assessment of the performance of fishways**. In the past, counting fish at the upstream end of fishways was the method used to assess performance. This does not provide information on the number of fish that were migrating but could not find the entrance of the fishway, or could not navigate the fishway. More sophisticated assessment techniques are required.
- **ecological interactions near and within a fishway**. For example, predators on migrating fish may accumulate near or within a fishway. It may be necessary to construct refugia for migrating fish.
- **species selective fishways.** It may be possible to allow the passage of native fish and block the migration of exotic fish (eg. European carp).

Clearly, there is much research to be done on fishways. Research at the CRCs for Freshwater Ecology and Catchment Hydrology, and other institutions is now focussing on some of these issues. The outcomes from these research programs will ultimately provide a sounder basis for the design of fishways. However, as native fish populations are declining and instream structures are a cause, the absence of some of this basic information should not be allowed to cause long delays with biologists and engineers together implementing their 'best-guesses' for fishway design (in the context of holistic stream rehabilitation plans). Fishways should be built with some flexibility (eg. movable baffles) so that some fine tuning can take place through time.

3. CONCLUSION

Provision of fish passage is an important issue in stream rehabilitation. Many native freshwater fish species in eastern Australia are migratory. Only a small proportion of instream structures in Australia have fishways. Further, not all of these fishways actually allow fish passage – particularly if the original design was for salmonid species and did not take account of the swimming ability and behaviour of local fish species.

Ensuring that migratory pathways for native fish are uninterrupted should be a key component of stream rehabilitation plans. Obtaining more basic information on fish passage issues should be a priority for stream rehabilitation research in Australia. As native fish populations are declining, the absence of some of this basic information should not cause long delays with biologists and engineers together implementing their 'best-guesses' for fishway design.

4. ACKNOWLEDGEMENTS

Thank you to Beth Thomson (Department of Fisheries and Oceans, Winnipeg, Canada) and Dr. Ian Rutherfurd (Monash University, CRC for Catchment Hydrology) for comments that were useful in finalising this paper. Thank you also to Martin Mallen-Cooper, who provided useful comments on a draft of the paper, and stimulating conversation during its preparation.

The primary author received many ideas used in this paper whilst on the AC Waters Travel Scholarship, provided by the Institution of Engineers, Australia.

5. REFERENCES

Bennett, P. (1997). Towards a State fishway program. Second National Fishway Technical Workshop, Rockhampton, Fisheries Group, Department of Primary Industries, Queensland.

Berghuis, A. P. (1997). Application of high level fishlocks in the Fitzroy River catchment. Second National Fishway Technical Workshop, Rockhampton, Fisheries Group, Department of Primary Industries, Queensland.

Harris, J. H. (1984). Impoundment of coastal drainages of south-eastern Australia, and a review of its relevance to fish migrations. Australian Zoologist **21**, 235-250.

Harris, J. H. and P. C. Gehrke (1997). Fish and rivers in Stress, The NSW Rivers Survey. Cronulla, NSW Fisheries Office of Conservation, CRC for Freshwater Ecology.

Jackson, P. (1997). Strategy for fish passage in Queensland. Second National Fishway Technical Workshop, Rockhampton, Fisheries Group, Department of Primary Industries, Queensland.

Koehn, J. 1995, Conserving Australian native freshwater fishes: the way forward., in People and Nature Conservation (Eds. A. Bennett, G. Backhouse and T. Clark), pp. 22 - 28 (Surrey, Beatty & Sons: Chipping North, Australia.

Leader, W. and K. Smit (1997). An integrated and holistic approach to solutions for fish passage in NSW. Second National Fishway Technical Workshop, Rockhampton, Fisheries Group, Department of Primary Industries, Queensland.

Mallen-Cooper, M. and Harris, J.H. (1990) Fishways in mainland south-eastern Australia. Proceedings of the International Symposium on Fishways '90 in Gifu. pp. 221-229.

Mallen-Cooper (1992). Fishways in Australia: past problems, present successes and future opportunities, Australian National Committee on Large Dams.

Mallen-Cooper, M. (1994). "How high can a fish jump?" New Scientist **142(121)**: 32-27.

Mallen-Cooper, M., I. G. Stuart, F. Hides-Pearson, J.H. Harris (1996). Fish migration in the River Murray and assessment of the Torrumbarry fishway. 1995 Riverine Environment Research Forum, Attwood, Victoria.

Mallen-Cooper, M. (1998), Fish passage options at tidal barrages in the Mary River Wetlands, Northern Territory, Report to the Northern Territory Department of Transport and Works.

Marsden, T. J., P. C. Gehrke, et al. (1997). Effects of Tallowa Dam on fish communities in the Shoalhaven River system. Second National Fishway Technical Workshop, Rockhampton, Fisheries Group, Department of Primary Industries, Queensland.

O'Brien, T. (1997). Rock fishways in Victoria. Second National Fishway Technical Workshop, Rockhampton, Fisheries Group, Department of Primary Industries, Queensland.

Parsons, G. R. and R. Smiley (1994). Swimming performance of white crappie, *Pomoxis Annularis*, the effect of environmental change. Oxford, University of Mississippi.

Raadik, T. A. (1992). Aquatic fauna of East Gippsland: fish and macroinvertebrates. Melbourne, Department of Conservation and Natural Resources.

Raadik, T. A. (1995). Native Fishes of Victoria - their significance, distribution and general biology. Willows, weeds and fishes, Berkely Lodge, Geelong.

Reynolds, L. F. (1983). Migration patterns of five fish species in the Murray-Darling River system. Australian Journal of Marine and Freshwater Research **34**, 857-871.